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FORWARD ERROR CORRECTION SCHEME FOR
HIGH RATE DATA EXCHANGE IN A WIRELESS SYSTEM

RELATED APPLICATION

This application is a continuation of U.S. Application No. 09/301,484, filed
5 April 28, 1999, the entire teachings of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

The present invention provides a low latency error correction mechanism for high data rate transmissions over multiple traffic channels in a wireless communication system.

10 It is known to include forward error correction ("FEC") coding and decoding to information signals that are to be transmitted over a wireless channel. Forward error correction, generally speaking, introduces predetermined redundancy into an information signal to permit a receiver to identify and perhaps correct errors that may have been introduced by a transmission medium. For example, the known IS-95
15 standard for code division multiple access cellular communication specifies a type of convolutional code for each traffic channel transmitted from base station to mobile station or vice versa.

Recently, it has been proposed to provide high data rate exchanges over a wireless communication system. Such high data rate exchanges may be used, for
20 example, to facilitate data transfer for computing applications or for video conferencing applications. In one such proposal, a high rate data signal may be communicated to a

receiver over a plurality of parallel traffic channels. For example, the recently proposed IS-95 B standard proposes use of parallel CDMA channels each having a data rate of 9.6 KB/s to provide a higher data rate communication. In such systems, a high rate data signal is demultiplexed into a plurality of lower rate data signals and each of these
5 signals is processed in an independent traffic channel. Thus, each lower rate data signal has FEC applied to it.

Another example of a wireless CDMA system providing multiple parallel traffic channels for high data rate exchange may be found in issued U.S. patent no. 6,151,332, entitled "Protocol Conversion and Bandwidth Reduction Technique Providing Multiple
10 nB+ D ISDN Basic Rate Interface Links Over a Wireless Code Division Multiple Access Communication System," the disclosure of which is incorporated herein.

Wireless communication channels are inherently "noisy" due to channel impairments caused by atmospheric conditions, multipath effects, co-channel interference and the like. Particularly if used for computing applications, where
15 executable content may be expected to be exchanged over traffic channels, the need for powerful FEC techniques will continue to be prevalent.

Use of more powerful FEC techniques in such wireless systems may increase the latency of data requests. For example, the known turbo codes require large blocks of data to be received entirely by a decoder before decoding can begin. Latency refers
20 generally to the delay that extends from the time a request for data is issued by a user and the time when data responsive to the request is presented to the user. FEC introduces decoding delays at a wireless receiver and, thus, contributes to latency. There is a need in the art for a wireless communication system that provides high data rate exchange having high quality FEC with low latency.

25 SUMMARY OF THE INVENTION

Embodiments of the present invention provide a transmitter/receiver system for high data transfer in a wireless communication system in which a physical layer processor comprises an FEC coder, a demultiplexer and a plurality of modem

processors. The FEC coder applies error correction codes to the high data rate signal. Thereafter, the demultiplexer distributes portions of the coded high data rate signal to the modem processors. Each modem processor processes its respective portion of the coded signal for transmission in an independent channel.

5 BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not
10 necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

FIG. 1 illustrates a transmitter and a receiver each constructed in accordance with embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

15 The present invention provides low latency forward error correction for a high data rate wireless transmission by applying forward error correction codes to data prior to multiplexing the data across a plurality of parallel fixed bandwidth traffic channels.

FIG. 1 is a block diagram of a transmitter 100 and a receiver 200 each constructed according to embodiments of the present invention. The transmitter 100
20 and receiver 200 are illustrated as operating in a layered communication system that includes a transmission layer (130, 230), a physical layer (120, 220) and higher layer communications such as network layers and data link layers (collectively labeled 110 and 210). As is known, in the transmission layer 130, a transmitter 100 performs carrier modulation, amplification and transmission upon digital data to be transmitted. Also as
25 is known, in the transmission layer 230, a receiver 200 performs reception, amplification and carrier demodulation to obtain a recovered digital data signal. The higher layers 110, 210 of the communication system also may process an information

signal as may be required for the application for which the present invention is to be used.

According to an embodiment of the present invention, the physical layer 120 of the transmitter 100 may be populated by an FEC coder 122, a demultiplexer 124 and a plurality of modem processors 126a-126n. The number of modem processors 126a-126n may vary and also may be determined by the quantity of data to be transmitted and the capacity of each of the traffic channels over which the data may be transmitted. The FEC coder 122 receives a source signal from a higher layer 110 in the transmitter and enhances it with an error correction code. The enhanced information signal is output from the FEC coder 122 to the demultiplexer 124. The demultiplexer distributes the information signal to the modem processors 126a-126n. The modem processors 126a-126n each format their respective portions of the enhanced signal for transmission. Outputs from the modem processors 126a-126n are summed by an adder 128 and delivered to the transmission layer 130.

At the receiver 200, the physical layer 220 performs processing that is the inverse of the processing that had been applied in the physical layer 120 of the transmitter 100. The physical layer 220 may be populated by an FEC decoder 222, a multiplexer 224 and a plurality of demodulators 226a-226n. There will be one demodulator 226a-226n for each of the traffic channels that had been allocated to carry the enhanced information signal. The recovered digital signal from the transmission layer 230 is input to each of the demodulators 226a-226n. Each demodulator 226a-226n outputs a recovered portion of the enhanced information signal. The multiplexer 224 merges each of the recovered portions of the enhanced information signal into a unitary recovered enhanced information signal. The FEC decoder 222 performs error detection and correction using error correction codes that had been introduced by the FEC coder 122 in the transmitter 100. The FEC decoder 222 outputs a corrected information signal to the higher layers 210 of the receiver 200.

In a CDMA embodiment, which is shown in FIG. 1, a receiver 200 need not include an element corresponding to the adder 128 of the transmitter 100; the

demodulators 226a-226n each perform correlation. As is known, correlation permits a modem processor to discriminate a desired CDMA signal from other CDMA signals that may be present in an aggregate received signal. Thus, in the embodiment of FIG. 1, the demodulators 226a-226n identify and output respective portions of the recovered enhanced information signal.

According to an embodiment of the present invention, the FEC coder 122 and FEC decoder 222 may generate and decode iterative systematic nested codes, also known as "turbo" codes. These turbo codes provide an advantage in that the FEC decoding process may be repeated iteratively to improve the information signal recovered therefrom. Thus, the output of a first iteration may be reintroduced to the FEC decoding block (path not shown in FIG. 1) for subsequent iterations. The nature of the turbo codes generates improved corrected data at subsequent iterations.

The known turbo codes, however, introduce a predetermined amount of latency into the decoding process. Turbo codes operate on blocks of a predetermined size. For example, one turbo code being considered for a wireless communication system for computer network applications possesses a block size of 4,096 channel symbols. An FEC decoder 222 must decode an entire block before a recovered information signal becomes available for the block. This characteristic may be contrasted with convolutional codes which are used in the known IS-95 standard for CDMA cellular communication; convolutional codes are characterized by relatively smaller latency for same-sized block (relative to turbo codes) because it is not necessary to receive an entire block before decoding may begin. It is believed that by distributing the FEC code among several parallel traffic channels as is shown in FIG. 1, the higher aggregate throughput of the traffic channels ameliorates the latency that would otherwise be introduced by the turbo code.

For high data rate applications using plural parallel traffic channels, it is believed that use of turbo codes achieves a higher figure of merit (lower E_b/N_0) than for convolutional codes. Using the example of a 4,096 channel symbol sized block and E_b/N_0 of 1.5 dB the turbo code provides a BER of 10^{-6} . By contrast, for voice systems

requiring a less stringent 10^{-3} BER, a convolutional code requires an E_b/N_0 of 7 dB or more.

The techniques of the present invention find application in a variety of wireless communication systems including CDMA systems. Typically, in application, the base stations and subscriber stations of the wireless communication system will include functionality of both the transmitter and receiver of FIG. 1. That is, to provide two-way communication, a base station will include a transmitter portion 100 and a receiver portion 200. So, too, with the subscriber terminal. The base stations and subscriber terminals may but need not be configured to provide simultaneous full-duplex communication.

Typically, a base station of a wireless communication system transmits a plurality of data signals to a variety of subscribers simultaneously. According to an embodiment of the present invention, each base station may perform the techniques disclosed herein simultaneously on a number of high rate data signals. It is consistent with the spirit and scope of the present invention that each signal may have a data rate that is independent of the data rates of the other signals. Thus, in such a case, a base station may be configured to include its FEC coder/decoders 122, 222 and modem processor/demodulators 126a, 226a in a pooled configuration. Such an embodiment permits the base station to assign, for example, a variable number of modem processors 126a-126n to a data signal depending upon the rate of the signal to be transmitted. Similarly, by including a pool of FEC coders 122 (shown singly in FIG.1) in a base station, the base station may selectively enable FEC coders 122 as the base station receives new data signals to be transmitted to subscribers. Provision of base station processing components in a pooled arrangement is well-known.

Several embodiments of the present invention are specifically illustrated and described herein. However, it will be appreciated that modifications and variations of the present invention are covered by the above teachings and within the purview of the appended claims without departing from the spirit and intended scope of the invention.